THURSDAY, AUGUST 6, 1891.

A PHYSICIST ON COLOUR-VISION.

Colour-Measurement and Mixture. By Captain Abney. (London: The Society for the Promotion of Christian Knowledge, 1891).

THIS interesting little book extends over only 200 pages, but is full of careful and important observations. It is, in fact, a summary of the results arrived at by the author during his careful and laborious investigation of the properties of the spectrum. It forms one of the "Romance of Science" series published by the S.P.C.K., a series intended "to show that science has for the masses as great an interest as, and more edification than, the romances of the day." Now, though the earlier portion of this book could be understood by anyone, we venture to think that the second half is for the most part so technical that the full meaning and value could only be appreciated by those who are more or less conversant with the methods of experimenting on colour. To those who are familiar to even a slight extent with the technicalities of colour experiments, the characteristic of the book is its extreme lucidity. We are carried on from point to point, until, when we look back on the closed book, we find we have travelled over the greater number of the problems of colour-vision almost without effort. It is a book which will not appeal to the masses, but should be read by every physiologist and physicist interested in colour-vision.

There is yet another reason for the interest which attaches to this work, necessitating a fuller notice than if it were simply a popular disquisition on colour. It is the record of a careful series of experiments by an eminent physicist, firmly convinced of the truth of the Young-Helmholtz theory of colour-vision. The voluminous work of Hering and his pupils is not once mentioned throughout the whole book, although König's later publications receive due notice. In fact, if space permitted, we cannot imagine a book more calculated to form the basis of a fruitful discussion on the merits of the rival theories than that now before us. For both the problems of colour-vision, and their solution according to the Young-Helmholtz theory, are definitely and clearly stated.

The book opens with a description of the methods used to obtain a spectrum, and a consideration of its properties with especial reference to the ultra-red and ultra-violet rays. The apparatus used by the author to investigate the three fundamental properties of colour—hue, luminosity, and purity—are described in detail. Absorption and interference are then touched upon in their relation to colour, and experiments are given to show that the colour of a body is due to its refusal to transmit or reflect certain rays of the spectrum. This is followed by an interesting chapter on scattered light, with especial reference to atmospheric effects, and a pretty lecture-room experiment is described to show that the change in the colour of the sun when on the horizon is produced by small particles in the air.

The author then passes on to consider the second property of colour—luminosity; and the luminosity of the spectral colours is measured as follows. The light from a certain portion of the spectrum passes through a slit which cuts off the remainder of the spectrum. A portion of the same white beam which was decomposed by the prisms is reflected on to the same screen as the monochromatic beam, and an upright rod is interposed. This rod throws two shadows, whose intensity is compared after the manner of a photometer. The luminosity of the whole reflected beam is greater than that of the coloured beam, and a rotating diaphragm, with variable sectors, is therefore interposed in its course. By altering the size of the sectors, the intensity of the white light is diminished, until the luminosity of the shadow it casts is equal to that cast by the monochromatic beam. The luminosity is then read off in terms of the segment of the circular diaphragm which remains open when the luminosity of the two shadows is equalized. The luminosity of all the principal points in the spectrum is measured on this plan. Subsequently the luminosity of a combination of red and green is shown to be equal to the sum of the luminosities of the same red and green determined separately. Three colours, A, B, and C, are chosen, which, when combined, make white of a certain intensity, W; and the author shows that if the luminosity of the combined light $A + B$ be subtracted from the luminosity of the white light, W, the remainder exactly equals the luminosity of the third factor, C.

A curve of luminosity can be constructed in this manner for the whole spectrum, and its maximum is found to lie on the yellow side of the D line. A similar luminosity curve is given for an observer who was what is ordinarily called red-blind. On this curve the red end of the spectrum is shortened, and the maximum luminosity falls nearer the green than on the curve constructed for a person with normal colour-vision. These facts are explained as follows. To the red-blind observer red is invisible, and therefore the luminosity of red is abolished; the luminosity of yellow, which is composed of red and green, is also diminished, and thus the maximum of the curve moves towards the green.

This question of luminosity is intimately associated with the theory of the value of white in the system of colour. The author discusses later on in the book the abolition of colour by white light, and examines the extent to which white light can be added to a colour without being perceived. He finds that both depend on the luminosity of the colour, and formulates the law that "the extinction of every colour is effected by white light that is 75 times brighter than the colour." Again, he finds that a large proportion of white light can be mixed with yellow without being perceived, whilst a very small proportion of white added to blue is at once apparent.

An attempt is made to explain these facts on the Young-Helmholtz theory; but the work done by Hillebrand,[1] under Hering's guidance, makes the explanation offered very improbable. Hillebrand used an apparatus in which one half of the field could be illuminated by a monochromatic spectral colour, whilst the other half was illuminated by white light. The observer shielded one eye from the light for a considerable time, so that it was ultimately brought into a condition of complete rest. Now if he looked at a field filled with monochromatic light of moderate intensity with the rested eye, it appeared to him colourless; and by suitable adjustment he could make an absolute match between the half of the field illuminated by monochromatic light and the other half illuminated by white light from the same source. Thus, as the whole spectrum appeared colourless, he was able to construct a curve of luminosity for the spectrum by matching it with the white light in the other half of the field. The maximum of this curve lay in the green. A glance with the unshaded eye at once brought the colour into view, although the field was unaltered. But as soon as the colour came into view, he noticed that the luminosity of the coloured half no longer matched that of the colourless half of the field. If yellow or red were the colour chosen, the luminosity of the coloured half of the field appeared to exceed that of the colourless half, whilst if green or blue were selected the exact opposite was observed. Moreover, as soon as the colours of the spectrum were appreciated, the maximum luminosity shifted into the yellow, and the curve he then obtained closely resembled that constructed by Captain Abney and other observers. Thus we must conclude that every part of the spectrum is capable of exciting the sensation of white apart from its specific colour, and that the maximum sensation is produced by a certain point in the green. As soon, however, as the colour becomes apparent, this sensation of white is either increased or decreased by the specific luminosity of the colour. The luminosity of the spectrum, as determined by Captain Abney, is the algebraic sum of two factors. Firstly, the power which every part of the spectrum possesses of exciting the sensation of white; and secondly, the specific luminosity of the colour sensation itself, which is a positive quantity on the red and yellow side and a negative quantity in the blue and green.

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[1] "Ueber die specifische Helligkeit der Farben," *Sitzb. d. k. Akad. d. Wissenschaft. in Wien*, February 1889.

If this explanation for the difference in the two curves be correct, a person who was completely deficient in colour-sense would construct a luminosity curve for the spectrum differing considerably in the position of its maximum from that given by Captain Abney in his book. The curve obtained by König[1] from a man to whom yellow, blue, green, and red were invisible, to whom the whole spectrum appeared in varying shades of white, shows that this is the case. The maximum luminosity lies in the green, over the line *b*. A comparison of this curve with that given by Hillebrand for the normal eye at rest reveals their almost absolute identity. The existence of this form of colour-blindness can only be explained with extreme difficulty on the Young-Helmholtz theory; whereas Hering's hypothesis, that white and black form a colour pair analogous to red and green, yellow and blue, not only renders the existence of such a condition probable, but also easily explains Hillebrand's results.

The author passes on to show that white can be produced from the mixture of three spectral colours, and ultimately defines a primary colour as one which cannot be formed by the mixture of any other colours. The three primary colours he selects are red, green, and violet; for yellow is formed by a mixture of red and green, blue by a mixture of green and violet. But he warns us from assuming that the three primary colour sensations "are of necessity the same sensations as are given by the three primary colours" (p. 138). On p. 150, red (between C and the lithium line), violet (close to G), are selected as furnishing two primary sensations, whilst "all three fundamental sensations" are excited by the green, except at a point where the green is mixed with white only.

Now, to say that spectral green excites the sensations of red and violet seems to us radically false. For when speaking of sensations we leave the realm of physics, and the sole test of the sensations excited by a portion of the spectrum is the colour which we perceive when light from that part impinges on the retina. No one who examines spectral green will say that it gives him the sensation of red or violet, but rather that the greater part of spectral green appears to be mixed with either yellow or blue. Again, a primary sensation must be one which gives us the sensation of one colour only. Now every eye sees in violet both blue and red. Thus, whether violet be a primary colour from the physical point of view, physiologically speaking it is anything but a primary sensation.

Though violet fails to answer the test of a primary colour sensation, a point can be found both in the yellow and the blue of the spectrum, from which the sensation of one colour only is obtained. But throughout the book we find repeated mention of the formation of yellow by the mixture of spectral red and spectral green. How can this be reconciled with the acceptance of yellow as a primary sensation?

To most eyes, the red of the spectrum yields to a greater or less extent the secondary sensation of yellow. Take such a red, and gradually add minute quantities of spectral blue. The yellow will gradually disappear, and a red will be produced, which yields the sensation of red only, untinged with either yellow or blue. Take a spectral green, which is also slightly yellow, and treat it in the same way. If we now mix the absolutely pure red with the absolutely pure green, white is produced, not yellow. And now we can understand why spectral red and spectral green can be made to form yellow. For both the red and the green, which, when mixed, form yellow, when separate give the secondary sensation of yellow in addition to that of their principal colour. Thus, when mixed, the pure red annihilates the pure green, and yellow only remains. Measured by this standard, the primary colour sensations fall into two groups, in which each colour is complementary to the other. Firstly, red and green, from which all secondary sensations of yellow and blue are absent; and secondly, yellow and blue, which do not give the secondary sensations of either red or green.

Colour-blindness is brought in to support the Young-Helmholtz theory, but the author has obviously not had the opportunity of investigating many cases of this affection. He speaks of green-blindness, in which the sensations of red and violet are present, but not that of green; and of red-blindness, in which the sensations of green and violet are present, but not that of red; and gives measurements to show that in the latter class of cases the spectrum is shortened.

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[1] "Die Grundempfindungen u. ihre Intensitäts-Vertheilung im Spectrum," *Sitzb. d. k. preus. Akad. d. Wissenschaft. zu Berlin*, xxxix, 1886. Hering has since shown, by investigating a similar case of total colour-blindness, how closely the curve of luminosity agrees with that given by Hillebrand. The account of this interesting case has not yet been published.

Now, Hering[1] has particularly investigated this portion of the subject, and explains the existence of two forms of colour-blindness as follows. He finds that persons with a normal colour-vision can be divided into two groups. The one class perceive yellow, the other blue, with exceptional ease, probably owing to a difference in the pigmentation of the media of the eye. The difference between the two groups is best seen with spectral green; for a green can be found which appears at the same time yellow-green to the one, blue-green to the other. To an observer with strong yellow vision, almost the whole of spectral red appears to be tinged with yellow, whilst a member of the second group, whose strong sense of blue prevents his seeing the yellow, pronounces the greater part to be pure red. Thus, the pure red and the pure blue are radically different colours for the two groups. Now, it is found that the pure red and the pure green formed for an observer with a strong sense of yellow appear grey to one who is what is called green-blind; whilst, on the other hand, the pure red or the pure green of the observer with a strong blue sense appears colourless to one who is red-blind. A red which is invisible to one who is "red-blind" is evidently coloured to a patient who is green blind, and he speaks of the colour he sees as red. But if a minute proportion of blue is added, the red gradually becomes purer until it becomes free from yellow to those of us who have a strong yellow sense. As the red becomes purer, our green-blind patient complains that the "red" is fading, and when finally the red is quite pure he matches the colour he sees with a grey, and says that the colour has gone. Thus, there is no fundamental difference between the red- and the green-blind. Neither group can perceive red or green. The only difference between them is one which we find amongst normal-sighted persons—namely, a different visual acuity for yellow and blue. The "red" of the green-blind is in reality the secondary sensation of yellow yielded by almost all the reds in nature, differing from the ordinary yellow in its limited power of exciting white. This peculiar yellow he has learnt to associate with what others around him call red, and he only betrays his affliction when all yellow is eliminated from the colour he calls red. Thus, a consideration of colour-blindness again leads us to throw red and green, blue and yellow, together into two groups as primary colour sensations.

Simultaneous contrast is touched on very superficially, and successive contrast is scarcely mentioned, yet the author again grasps at the three-colour theory to explain the few phenomena he mentions. Yet it is notorious that the Young-Helmholtz theory fails to afford any adequate explanation of the phenomena of contrast. It was by an ingenious contrast experiment that Hering produced such a striking confirmation of his views before the Physiological Congress at Basle, and placed the three-colour theory in a dilemma from which its ablest exponents have not yet succeeded in extracting it.

In conclusion, the book before us is an admirable summary of a valuable series of experiments. We can scarcely imagine that it will appeal to the public in general. But it should be read by those who are interested in the phenomenon of colour-vision, and the fact that the author frankly accepts the three-colour theory and ignores the work of Hering does not, in our opinion, detract from its value. For the book thus becomes an admirable statement of the strongest portion of the physical theory of colour by one of the ablest of English physicists.

H. H.

POSITIVE SCIENCE AND THE SPHINX.

Riddles of the Sphinx. A Study in the Philosophy of Evolution. By a Troglodyte. (London: Swan Sonnenschein, 1891.)

THESE be old old riddles that the Sphinx propounds and the Troglodyte attempts to guess, in the volume before us; none other, indeed, than the What, Whence, and Whither of man and of the world. There have been other guesses in the past, there will be other guesses while time lasts; each guesser thinks his own guess nearer the true answer than any other; his neighbours mostly smile, unless his guess chances to be something like their own; and the Sphinx looks on with stony stare, imperturbable, giving no hints.

So soon as man, as man, looked out upon the world, and began dimly to realize the first personal pronoun, the nascent reason, or, if the phrase be preferred, intellectual faculty, demanded, for the first time in the history of the development of consciousness, an explanation. Man, then as now the chief centre of interest to man, must thenceforward not only live and act, but must seek to explain his life, and his activity. Yesterday the tribe-chief went forth a living man, feared by all: to-day his body is brought back, helpless, lifeless, and a hog spurns it with his snout. How account for this? How explain this change? Something there was about the man yesterday which made him totally different from the mere mass of clay that to-day already needs hustling out of sight. That something, call it soul, spirit, energy, life, what you will, has departed. Whither has it gone?

This question, eminently natural, almost inevitable, opened the way for reason's first blunder to enter and to become a fruitful mother of children. Reason, in the exercise of the new-born analytic faculty, distinguished between the mere body and the informing something through which it was a living body; between the material substance and the spirit-energy which was associated with that substance during life. But reason also jumped to the conclusion that what were distinguishable in thought were also capable of separate existence in fact. The matter remains in the corpse, but the something, the spirit-energy, has escaped, to lead a distinct and independent existence. In justification of this conclusion the phenomena of dreams were no doubt adduced as evidence. While the chief's body was lying stark and stiff, his true self, his spirit-energy, appeared by night to more than one of his chosen followers. Thus the dream seemed to support the false conclusion of the nascent reason, which had not yet learnt to distinguish without dividing.

It has cost positive science much labour, and not a few hard blows, to establish, by detailed work in physical science, biology, neurology, and psychology, the ille-

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[1] "Zur Erklärung d. Farbenblindheit" (Prag, 1880); "Ueber Individuelle Verschiedenheiten des Farbensinnes" (Prag, 1885); "Eine Vorrichtung z. diagnose d. Farbenblindheit," "Ueber d. Erklärung d. peripháren Farbenblindheit," "Einseitige Störungen d. Farbensinnes," *Archiv f. Ophthalmologie*, xxxvi.